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Method and arrangement for purifying the gases that are to be fed to a fuel cell for operation by removing constituents which are unfavorable to the fuel cell operation

The invention relates to a method and an arrangement for purifying the gases that are to be fed to a fuel cell for operation by removing constituents which are unfavorable to the fuel cell operation.

On account of their high efficiency and the low levels or absence of pollutant emissions, fuel cells are also used in electric vehicles. By way of example, an electric vehicle is known which has a driving motor, a fuel cell and a fuel tank, a water store, an evaporator and a reformer. The fuel tank contains methanol which, together with water from the water store, is converted into the gaseous state in the evaporator and is then passed to the reformer, in which substantially hydrogen, carbon dioxide and carbon monoxide are formed with heat being supplied by means of a catalytic burner. The carbon monoxide can be oxidized with an oxidizing agent. The hydrogen-containing fuel gas from the reformer is fed to the fuel cell by means of a compressor; the fuel cell comprises a fuel cell stack in which a multiplicity of individual fuel cell modules are integrated. Humidified air is fed to the fuel cell by a further compressor. Electrical energy for the electric driving motor is generated in the fuel cell from the hydrogen and from the oxygen of the air (DE 44 12 450 A1).

Membrane fuel cells, which in each case have a proton-conducting ion exchange membrane made from a polymer material, e.g. fluorinated resin, with a very good electrical conductivity in the moist state, are also

used in electric vehicles. The membrane surface is covered with a catalyst. On one side, the electrolyte membrane is connected to a gas-permeable anode, and on the other side it is connected to a gas-permeable cathode. A ribbed, gas-impermeable plate adjoins the anode; the cavities between the ribs of this plate serve to supply the oxidizing gas, e.g. air with an oxygen content. A gas-impermeable ribbed plate likewise adjoins the cathode, and its cavities between the ribs are used to supply the gaseous fuel, e.g. the hydrogen-containing gas. When the fuel cell is operating, the electrolyte membrane is moistened by the water of reaction and the humidity in the gases supplied.

A fuel cell in a fuel cell system requires sufficiently purified gases and/or gas mixtures, both with regard to the fuel gas and with regard to the oxidizing gas, for it to operate if the original gas contains constituents which have an adverse effect on the mode of operation of the fuel cell. In this context, the term fuel cell is to be understood as meaning both an individual fuel cell module with the structure as described above and a stack of fuel cell modules of this type which can be connected in parallel and/or in series. If the oxidizing gas used is air which is drawn in from the atmosphere, it is generally necessary to carry out a purification step. When using hydrogen which is taken from a tank or is generated from a liquid fuel, it is often the case that there are no disruptive constituents in the gas, and consequently there is no need for any purification.

The invention is based on the problem of providing a method and an arrangement for eliminating contaminating substances from the gases for operation of a fuel cell before the gases are fed into the fuel cell.

In a method of the type described in the introduction,

the object is achieved, according to the invention, by the fact that the gas(es) are passed across a filter system which is designed both to separate off particulates and to remove constituents in gas and vapor form which have a damaging effect on operation of the fuel cells, and that the gas(es) are fed to the fuel cell on leaving the filter system. The method according to the invention removes not only particulates, such as dust and carbon particles, but also further constituents of the gas, such as polluting gases, aerosols, organic substances, such as algae, spores, bacteria and viruses, from the gas or gases, which are also referred to below as reaction gases, although they may comprise a mixture of gases, not all of which react in the fuel cell or contribute to the generation of electric power. The purification of the gas or gases makes it possible to lengthen the operating time or service life of the fuel cell.

In particular, the gas(es) are passed across a filter system which can be regenerated and is monitored on the basis of criteria indicating a drop in the filter action and that the regeneration should be carried out, with a message being generated when these criteria are reached. The regeneration is carried out when the fuel cell is inoperative. This makes it possible to avoid damage to the fuel cell in the event of spontaneous releases of pollutants during regeneration.

In an arrangement of the type described in the introduction, the object is achieved, according to the invention, by virtue of the fact that a filter system is arranged at a location in the gas-carrying passage for feeding the gas to be purified to the fuel cell, which filter system separates out both particulates and constituents in gas or vapor form which have a damaging effect on operation of the fuel cell. The purification of the respective reaction gas using the filter system

prevents impurities from being deposited in the feed passages, in delivery means and in the fuel cell itself, thereby gradually causing the function of the fuel cell to deteriorate, or prevents polluting gases from causing undesirable reactions in the fuel cell.

In an expedient embodiment, the filter system has a first filter for particulates, downstream of which there is a second filter with a substance for taking up and binding pollutants in gas or vapor form. Dry filters made from plastic, glass fiber, paper with a high level of dedusting can be used as the first filter and may, for example, have a labyrinth-like structure. The second filter includes in particular porous substances for taking up and physically or chemically binding gases or vapors at the surface. Examples of substances of this type include activated carbon or kieselguhr.

In another expedient embodiment, the filter system comprises a unit in which a dry filter for particulates and a substance for taking up and binding gases or vapors at its surface are arranged together. Therefore, the filter system combines the functions of particulate separation and removal of polluting gases. It is expedient for the particulate filter to include a substance for binding and/or separating off gases, which is arranged on a material for separating out particulates or is self-supporting or forms a bulk bed.

In one preferred embodiment, the filter system is designed such that it can be regenerated, it being possible for the regeneration to be triggered by an actuating element. This makes it possible to prevent the regeneration from being triggered spontaneously, e.g. when the fuel cell is operating, which can lead to high levels of pollutants being emitted and therefore to damage to the fuel cell. The regeneration of the

first filter can be carried out, for example, using compressed air, whereas the regeneration of the second filter can be effected by increasing the temperature, since the adsorption is lower at a higher temperature than at a lower temperature.

It is advantageous if the filter system is arranged in the gas-carrying passage for the oxidizing gas upstream of the gas inlet of a compressor. The gas-carrying passage may be arranged inside or outside the fuel cell system to which the fuel cell belongs.

To establish the need for regeneration or filter maintenance with regard to particulate separation, in particular the pressure difference between the pressure upstream and downstream of the filter system is compared with a predeterminable limit value, with a message being generated if the latter is exceeded.

With regard to the adsorption of pollutants, the need to regenerate or carry out maintenance on the filter can be established using one or more gas or pollutant sensors downstream of the filter system, which are set to measure the pollutants which are to be separated off and the measured values from which are compared with a limit value in each case, with a message being generated if the latter is exceeded.

The invention is described in more detail below on the basis of an exemplary embodiment illustrated in the drawing, from which further details, features and advantages will emerge. In the drawing:

Fig. 1 shows a fuel cell system having a filter system for removing contaminating constituents contained in the gases to be fed to a fuel cell, in the form of a diagrammatic, partially sectional illustration,

Fig. 2 shows another embodiment of a filter system for the fuel cell system illustrated in Fig. 1.

A fuel cell system 1, which, in a manner known per se, includes a fuel cell 2, for example of the type having an electrolyte membrane, and further components, which are not shown in the drawing, such as a fuel tank, a water store, an evaporator, a reformer and a control unit, also includes at least one apparatus 3 for sucking in and compressing a gas. This gas is, for example, air, the oxygen in which represents the oxidizing gas which in the fuel cell 2 reacts with the gaseous fuel to generate electrical energy. The gaseous fuel is, for example, hydrogen.

The apparatus 3 includes a compressor 4 which sucks in and compresses the air. The compressed air passes to the fuel cell 2 via passages (not shown in more detail) and if appropriate a control or metering valve. The compressor 4 used is, for example, a centrifugal compressor which is driven by an electric motor (not shown). On account of the relatively high efficiency and low emission of pollutants, fuel cell systems are also used in mobile apparatuses, such as motor vehicles. Small component dimensions and low weights are of importance in these applications.

The apparatus 3 also includes a filter system 5 which is used to purify the gas sucked in by the compressor 4. The filter system 5 is a multi-stage combination filter having a first filter 6, which is used to separate particulates out of the intake air stream, and a second filter 7, which is used to separate certain gases, aerosols and vapors out of the intake air stream. The first filter 6 has a plurality of filter sections. A first filter section 8, which is designed in particular as a porous intake passage, acts as a

coarse filter for separating out particulates, such as carbon particles or dust. A second filter section 9 operates as a fine filter for particulate separation, for example for removing organic substances, such as pollen, diesel carbon particulates in the intake air. If air which is particularly free of dust and particulates is to be generated, a third filter section 10 in the form of an ultrafine filter is provided and is used to separate out, for example, bacteria, viruses and spores. The filter sections 8, 9, 10 are, for example, dry filters. Whereas the filter section 8 may consist of a textile fabric, the filter sections 9 and 10 are composed of labyrinth-like cells which consist of plastic, glass fiber, paper or textiles. A nonwoven design is also possible.

The second filter 7, the outlet opening of which is connected to the compressor 4 through a gas-carrying passage 11, directly adjoins the first filter 6. The second filter 7 separates out gases which interfere with operation of the fuel cell 2 and are referred to below as polluting gases. Adsorbents, such as activated carbon and kieselguhr, which can take up and bind gases and vapors at their surface, can be used to separate out the polluting gases. The air which is sucked in by the compressor 4 leaves the second filter 7 as a clean gas.

A sequence of the filter functions which differs from that described above is also possible. The sequence depends on the substances/particulates to be filtered out and the specific structure of the filter system 5. In addition to the separation or binding of the polluting gases by adsorbents or other suitable substances, it is also possible for the polluting gases to be guided out of the air supply system.

Mechanical means, such as those referred to above in connection with the particulates, or chemical, electrostatic or optical methods which are known per se can be used for the filtering. A combination of these methods is also possible. In the case of optical filtering methods, for example, UV or IR rays are used.

The combination of an electrostatic filter with ionization with filters made of fibrous substances in front of and/or behind it is also expedient, so that the electrostatic filter is acted on uniformly and relatively large particles which have not been separated out in the electrostatic filter or are entrained again are removed from the air stream.

Fig. 2 diagrammatically depicts a sectional view through a filter system 12, which includes both the elements for particulate separation and for the physical and/or chemical binding of polluting gases, aerosols and vapors, in a single unit. A porous substance for binding or separating off gases is arranged on a carrier material 13 in the form of a labyrinth of cells of fibers. The porous substance on the carrier material 13 is represented by dots (not shown in more detail) in Fig. 2. The substance may be self-supporting or may also form a bulk bed. The filter system 12 is arranged between an intake passage 14 and the gas-carrying passage 11 leading to the compressor 4.

It is possible to use a filter system that can be regenerated. The filter system 12 diagrammatically represents one such system. Compressed air, which originates, for example, from a compressed air generator 15 connected to the filter system 12, can be used for the regeneration in order to remove the particulates which have been separated out. Gases which have been bound by the substance can be released by

heating the filter system 12 in order to regenerate the filter system 12. The regeneration requires additional devices, such as the blocking of the gas-carrying passage 11 and the opening of apertures for discharging the particulates and gases released. These additional devices are not shown in Fig. 2.

The regeneration is expediently carried out while the fuel cell 2 is inoperative. To avoid spontaneous emissions of pollutants from the filter system during regeneration, automatic regeneration is not provided for. There is a control unit 17 which can be acted on by an input element, e.g. button 16, and which determines the sequence of regeneration. The control unit 17 is caused to initiate and carry out the filter regeneration through actuation of the button 16.

It is also possible for some or all of the filter system to be designed such that it cannot be regenerated and for the parts or the filter system to be replaced during maintenance.

The accumulation of particulates causes the pressure difference across the filter systems 5 and 12 to rise. The pressure difference can be measured using an appliance, e.g. manometer 18, and the measured value can be compared with a predeterminable limit value; when this limit value is reached, a message is generated with the intention of indicating the need to change the filter or carry out a regeneration operation. It is also possible for the quantity of polluting gases taken up by an adsorbent to be checked for maintenance purposes by a sensor (not shown) which is suitable for determining the levels of pollutants that have been adsorbed, being arranged in the gas-carrying passage 11. If the sensor detects a predeterminable limit value for the pollutant(s), a message is likewise generated. The measured values from

the manometer 18 and the at least one pollutant sensor are transmitted to an evaluation unit 19, in which they are compared with the predeterminable limit values.

The triggering of the filter regeneration can be effected not only mechanically but also by electrical or optical means, in particular when the fuel cell system is inoperative.

The filtering of the reaction gases retains or removes both particulates and gases, e.g. gritting salt, which is also dissolved and dispersed in the atmospheric humidity. Gritting salt (deicing salt) is, for example, spread in winter and may be a constituent of the air which is sucked in.

The filtering of the reaction gases in accordance with the invention prevents faults in the fuel cell system as a result of pollutants being fed into the fuel cell, and thereby increases the service life or operating time of the fuel cell.

An arrangement of the type described above is advantageously used in a mobile apparatus, such as a vehicle, e.g. a motor vehicle, a locomotive or a boat.